(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Veröffentlichungsnummer:
(11) Publication number:
(11) Numéro de publication:

EP 1 576 582 A0

Internationale Anmeldung veröffentlicht durch die Weltorganisation für geistiges Eigentum unter der Nummer:

WO 2004/049117 (art. 158 des EPÜ).

International application published by the World Intellectual Property Organisation under number:

WO 2004/049117 (art. 158 of the EPC).

Demande internationale publiée par l'Organisation Mondiale de la Propriété sous le numéro:

WO 2004/049117 (art. 158 de la CBE).

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
10 June 2004 (10.06.2004)

PCT

(10) International Publication Number
WO 2004/049117 A2

(51) International Patent Classification[7]: G06F

(21) International Application Number: PCT/US2003/037170

(22) International Filing Date: 19 November 2003 (19.11.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
10/302,309 22 November 2002 (22.11.2002) US

(71) Applicant: **ARBITRON INC.** [US/US]; 9705 Patuxent Woods Drive, Columbia, MD 21046 (US).

(72) Inventors: **JENSEN, James, M.**; 10702 Faulkner Ridge Circle, Columbia, MD 21044 (US). **NEUHAUSER, Alan, R.**; 1512 Flora Court, Silver Spring, MD 20910 (US).

(74) Agents: **FLANAGAN III, Eugene, L.** et al.; St. Onge Steward Johnston & Reens LLC., 986 Bedford Street, Stamford, CT 06905-5619 (US).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZM, ZW.

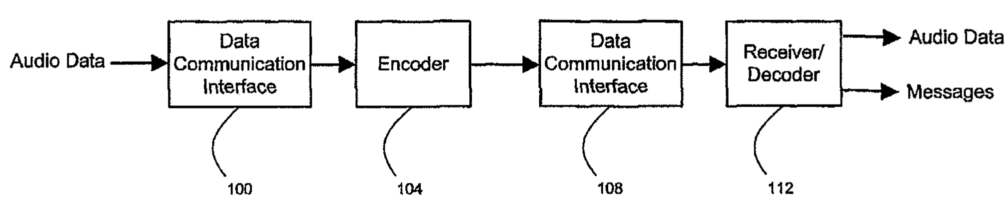
(84) Designated States *(regional)*: ARIPO patent (BW, GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

WO 2004/049117 A2

(54) Title: ENCODING MULTIPLE MESSAGES IN AUDIO DATA AND DETECTING SAME



(57) Abstract: Systems and methods are provided for encoding and decoding multiple messages in audio data. The messages each comprise a sequence of message symbols each comprising a combination of substantially single-frequency components. At least some of the message symbols in one of the messages coexist with at least some of the symbols of another one of the messages along a time base of the audio data.

PATENT
03382-P0087AWO ELF/DJV

Title Of Invention

ENCODING MULTIPLE MESSAGES IN AUDIO DATA AND DETECTING SAME

Field Of The Invention

[001] The present invention relates to apparatus and methods for including multiple overlapping encoded messages in audio data and decoding such encoded messages.

Background Of The Invention

[002] There are many reasons to encode an inaudible message in audio data and many groups would like to have access to such technology. A group with such an interest is the group of copyright owners. Copyright owners would like such an encoding technique to facilitate copyright enforcement and protection. Copyright enforcement would be facilitated by encoding pieces of copyrighted works with a watermark to provide ownership information for copyright enforcement. Alternatively, the copyrights of a work may be protected by a copy protection scheme, e.g. encryption keys encoded onto the audio data, which would prevent unauthorized use of the protected matter.

[003] Another group with an interest in using inaudible messages encoded into audio data would be the group of audio listeners. The encoding would provide listeners with useful information about the programs they are listening to without affecting the audio experience. For example, the names of the performers, the name of the performance, or the name of the broadcaster may be given and relayed to the listener via the listener's receiver.

[004] Still another group with an interest in the encoding of inaudible messages into audio data would be market researchers who make use of audience estimating techniques, as well as customer loyalty programs, commercial verification functionality and program identification. Inaudible messages encoded into broadcast or recorded audio are particularly useful in implementing such techniques and activities.

[005] Yet still another group with an interest in the encoding of inaudible messages into audio data would be those seeking additional bandwidth to communicate data that is totally unrelated to the audio data. For example, telecommunications companies could utilize the bandwidth to carry their data and/or news organizations could relay real time news such as breaking headlines or stock quotes.

[006] There are many other good reasons that other interested groups have for the encoding of inaudible messages into audio data. One problem encountered in attempting to encode multiple messages inaudibly within audio data is that there is only a limited amount of bandwidth available for this purpose.

[007] The limited bandwidth is due to the fact that audio data can only receive a finite amount of energy in the encoding process before the encoding becomes audible. This level of acceptable ancillary data energy in audio data is application dependent. For example, in high fidelity applications such as music distribution or broadcasting, the messages must be keep inaudible. However, in certain other applications such as voice data communication, e.g. cell phone communications, the constraints on the amount of acceptable ancillary data energy in the audio data are less rigorous. The bandwidth limitations due to these constraints are further restricted by the administrative load imposed by error detection and correction data, marker data, sync data, address data and the like.

[008] A further problem arises in applications requiring the encoding of one or more messages in audio data that is already encoded with another message. This is desired in certain broadcast and recording applications, such as audience measurement, commercial and network clearance, and content identification. It has been proposed to reserve different respective time intervals along the time base of the audio data for encoding of plural messages at various levels of distribution (for example, at the production level, the network level and the local affiliate level). Such time division multiplexing of encoded messages substantially restricts bandwidth available for each of the messages and requires a reliable means of determining in each case the permissible time interval for inserting each different message.

[009] Accordingly, what is needed is a way to encode multiple messages inaudibly in audio data in which one or more such messages are encoded in the audio data at different times and/or levels of distribution which achieves desirably high bandwidth and is easily implemented.

[0010] It is also desired to provide expanded data communication capability in the limited bandwidth available for ancillary data in an audio channel. It is desired, therefore, to increase the bandwidth afforded by an audio channel to communicate information in the form of ancillary data encoded in the audio data, so that the encoded ancillary data remains inaudible or beneath an acceptable level of audibility when the audio data is reproduced acoustically.

Summary Of The Invention

[0011] For this application the following terms and definitions shall apply, both for the singular and plural forms of nouns and for all verb tenses:

[0012] The term "data" as used herein means any indicia, signals, marks, domains, symbols, symbol sets, representations, and any other physical form or forms representing information, whether permanent or

temporary, whether visible, audible, acoustic, electric, magnetic, electromagnetic, or otherwise manifested. The term "data" as used to represent particular information in one physical form shall be deemed to encompass any and all representations of the same particular information in a different physical form or forms.

[0013] The term "audio data" as used herein means any data representing acoustic energy, including, but not limited to, audible sounds, regardless of the presence of any other data, or lack thereof, which accompanies, is appended to, is superimposed on, or is otherwise transmitted or able to be transmitted with the audio data.

[0014] The term "processor" as used herein means data processing devices, apparatus, programs, circuits, systems, and subsystems, whether implemented in hardware, software, or both, and whether used to process data in analog or digital form.

[0015] The terms "communicate" and "communicating" as used herein include both conveying data from a source to a destination, as well as delivering data to a communications medium, system or link to be conveyed to a destination. The term "communication" as used herein means the act of communicating or the data communicated, as appropriate.

[0016] The terms "coupled", "coupled to", and "coupled with" as used herein each mean a relationship between or among two or more devices, apparatus, files, programs, media, components, networks, systems, subsystems, and/or means, constituting any one or more of (a) a connection, whether direct or through one or more other devices, apparatus, files, programs, media, components, networks, systems, subsystems, or means, (b) a communications relationship, whether direct or through one or more other devices, apparatus, files, programs, media, components, networks, systems, subsystems, or means, or (c) a functional relationship in which the operation of any one or more of the relevant devices, apparatus, files,

programs, media, components, networks, systems, subsystems, or means depends, in whole or in part, on the operation of any one or more others thereof.

[0017] In accordance with an aspect of the present invention, a method is provided for encoding audio data with a message, the audio data having a preexisting message encoded therein comprising a sequence of preexisting message symbols in a first format, the preexisting message symbols each comprising a combination of substantially single-frequency components having frequencies selected from a predefined set of substantially single-frequency values. The method comprises providing data defining a plurality of further message symbols each comprising a combination of substantially single-frequency components selected from a predefined set of substantially single-frequency values; and encoding the audio data with a further message comprising a sequence of the further message symbols in a second format differing from the first format, such that at least some of the further message symbols of the further message coexist with at least some of the preexisting message symbols of the preexisting message along a time base of the audio data.

[0018] In accordance with a further aspect of the present invention, a method is provided for encoding audio data with first and second messages each comprising a sequence of first and second message symbols, respectively. The method comprises providing data defining the first and second message symbols to comprise a combination of substantially single-frequency values selected from a predefined set of substantially single-frequency values; encoding the audio data with the sequence of first message symbols of the first message in a first format; and encoding the audio data with the sequence of second message symbols of the second message in a second format differing from the first format, such that at least some of the first message symbols of the first message co-exist with at least some of the second message symbols of the second message along a time base of the audio data.

[0019] In accordance with another aspect of the present invention, a method is provided for detecting a first message and a second message encoded in audio data as a sequence of first and second message symbols, respectively, at least some of the first message symbols coexisting with at least some of the second message symbols along a time base of the audio data, each of the first and second message symbols comprising a combination of substantially single-frequency components having frequencies selected from a predefined set of substantially single-frequency values, the first sequence of message symbols having a first format and the second sequence of message symbols having a second format differing from the first format. The method comprises detecting the first message symbols based on the first format thereof; and detecting the second message symbols based on the second format thereof.

[0020] In accordance with a still further aspect of the present invention, a system is provided for encoding audio data with a message, the audio data having a preexisting message encoded therein comprising a sequence of preexisting message symbols in a first format, the preexisting message symbols each comprising a combination of substantially single-frequency components having frequencies selected from a predefined set of substantially single-frequency values. The system comprises means for providing data defining a plurality of further message symbols each comprising a combination of substantially single-frequency components selected from a predefined set of substantially single-frequency values; and means for encoding the audio data with a further message comprising a sequence of the further message symbols in a second format differing from the first format, such that at least some of the further message symbols of the further message coexist with at least some of the preexisting message symbols of the preexisting message along a time base of the audio data.

[0021] In accordance with a yet still further aspect of the present invention, a system is provided for encoding audio data with first and second messages each comprising a sequence of first and second message symbols,

respectively. The system comprises means for providing data defining the first and second message symbols to comprise a combination of substantially single-frequency values selected from a predefined set of substantially single-frequency values; and means for encoding the audio data with the sequence of first message symbols of the first message in a first format and for encoding the audio data with the sequence of second message symbols of the second message in a second format differing from the first format, such that at least some of the first message symbols of the first message co-exist with at least some of the second message symbols of the second message along a time base of the audio data.

[0022] In accordance with still another aspect of the present invention, a system is provided for detecting a first message and a second message encoded in audio data as a sequence of first and second message symbols, respectively, at least some of the first message symbols coexisting with at least some of the second message symbols along a time base of the audio data, each of the first and second message symbols comprising a combination of substantially single-frequency components having frequencies selected from a predefined set of substantially single-frequency values, the first sequence of message symbols having a first format and the second sequence of message symbols having a second format differing from the first format. The system comprises means for detecting the first message symbols based on the first format thereof and for detecting the second message symbols based on the second format thereof.

[0023] The invention and its particular features and advantages will become more apparent from the following detailed description considered with reference to the accompanying drawings.

Brief Description Of The Drawings

[0024] FIGURE 1 is a functional block diagram of a communications system incorporating an encoder and receiver/decoder in accordance with certain embodiments of the present invention;

[0025] FIGURE 2 is an overview of an encoding process in accordance with certain embodiments of the present invention;

[0026] FIGURES 2A and 2B illustrate exemplary symbol sequences for first and second messages, respectively, to be encoded in audio data;

[0027] FIGURES 2C and 2D illustrate exemplary schemes for assigning substantially single-frequency components to the symbols of the first and second messages of Figures 2A and 2B;

[0028] FIGURES 2E through 2I illustrate examples of multiple messages encoded in audio data by means of various embodiments of the present invention;

[0029] FIGURE 3 is an overview of an embodiment of a decoding process and system using multiple buffers in accordance with certain embodiments of the present invention;

[0030] FIGURE 4 is an overview of another embodiment of a decoding process and system using a single buffer;

[0031] FIGURE 5 is an overview of a process for encoding two messages in audio data in accordance with certain embodiments of the present invention;

[0032] FIGURE 6 is an overview of a further embodiment of an encoding process and system for encoding two messages in audio data;

[0033] FIGURE 7 is an overview of a process and system for encoding multiple messages in time domain audio data in accordance with certain embodiments of the present invention;

[0034] FIGURE 8 is an overview of a process in accordance with certain embodiments of the present invention for encoding multiple messages in audio data so that the messages are repeated continuously in the audio data;

[0035] FIGURE 9 is an overview of an analog process and system for encoding multiple messages in analog audio data in accordance with certain embodiments of the present invention; and

[0036] FIGURE 10 is an overview of an encoder in accordance with certain embodiments of the present invention implemented by means of a processor.

Detailed Description Of Certain Advantageous Embodiments

[0037] Methods and systems are provided for encoding multiple messages in audio data. In certain embodiments one or more such messages are encoded into audio data having a previously encoded message therein. In certain other embodiments, two or more messages are encoded into audio data that contains no previously encoded message. Each of two or more messages encoded in the same time interval of the audio data has a different format or symbol set to enable the messages to be separately decoded. Each such different format or symbol set characterizes a distinct separately decodable message space or message layer.

[0038] In certain embodiments of the invention, multiple messages are encoded in compressed audio data. In particular ones of these embodiments the encoding of compressed audio is accomplished by modifying existing frequency representations of the audio data. In certain embodiments uncompressed audio data is encoded.

[0039] Embodiments of the invention are provided to encode multiple messages in audio data in the frequency domain in any of multiple formats, e.g. compressed or uncompressed, whether previously encoded or unencoded. Embodiments are also provided to encode multiple messages into audio data in the time domain in any of multiple formats, e.g. compressed or uncompressed, and whether previously encoded or unencoded.

[0040] Certain embodiments encode multiple simultaneous messages while reusing frequency components selected from the same set of frequencies by assigning the reused frequency components in different combinations in the two different message layers. By reusing frequency components, the system's bandwidth increases because more symbols may be encoded in a given interval of the audio data.

[0041] In certain embodiments, one or more messages are encoded in audio data having one or more messages encoded therein, utilizing different message lengths for the various messages, differing symbol intervals in different messages, differing offsets of the various messages from one another and/or different combinations of frequency components assigned to their respective symbols. In certain embodiments the multiple messages are detected based on their differing message lengths, differing symbol intervals, differing message offsets and/or symbol frequency component combinations.

[0042] In certain embodiments, encoded messages that share frequency components are decoded. The decoder accumulates the energy for each message symbol into a buffer and then uses a predetermined symbol/frequency component combination relationship to interpret the accumulated energy in the buffer thereby identifying the substantially single-frequency components. Once the substantially single-frequency components are identified, the symbol and then the message can be reconstructed.

[0043] FIGURE 1 is an overview of encoding and decoding processes and systems in accordance with certain embodiments of the

invention. The audio data represented in FIGURE 1 can come in many forms. The audio data can be in a compressed or uncompressed format. The audio data can be previously encoded or unencoded. The audio data can be represented in the time domain or the frequency domain. The audio data can also have any combination of the foregoing audio data forms.

[0044] Audio data, regardless of its form as described above, enters the system through a communications interface 100. This communications interface 100 utilizes any of the readily available technologies such as a serial port, parallel port, coaxial cable, twisted wire, infrared port, optical cable, microwave link, rf, wireless port, satellite link or the like.

[0045] The audio data then enters encoder 104 from communications interface 100. In encoder 104, in one mode of operation the audio data is encoded with multiple messages that share substantially single-frequency components. In another, the audio data as received by encoder 104 has a message encoded therein and encoder 104 encodes one or more additional messages in the audio data. The encoded audio data is then communicated via a communication interface 108. The communication interface 108 can come in any of multiple forms such as radio broadcasts, television broadcasts, DVDs, MP3s, compact discs, streaming music, streaming video, network data, mini-discs, multimedia presentations, VHS tapes, personal address systems or the like. Receiver 112 then receives the communicated encoded audio data.

[0046] Receiver 112 possesses a decoder to detect the encoded messages. As a result of the ability to retrieve the encoded messages, the receiver 112 can therefore possess a myriad of functionality. Functionality such as the relaying of information, e.g. providing the performing artist's name or providing audience estimating information, or controlling access, e.g. an encryption key scheme, or data transport, e.g. using the encoded messages as an alternate communications channel. The receiver 112 can possess the ability to reproduce the audio data but this is not essential. For example, a

receiver 112 used for gathering audience estimate data can receive the audio data in acoustic form, in electrical form or otherwise from a separate receiver. In the case of an encryption key scheme, the reproduction of the audio data for an encryption key holder is the objective.

[0047] FIGURE 2 is an overview of encoding processes and systems according to certain embodiments of the invention. Block 116 illustrates a number of preliminary operations 120, 124 and 128 which are carried out in preparation for encoding one or more messages into audio data. As indicated by operation 120, the content of a message to be encoded is defined. In certain embodiments this is achieved by selecting from a plurality of predefined messages, while in others the content of the message is defined through a user input or by data received from a further system. In still others the identity of the message content is fixed.

[0048] Once the content of the message is known, a sequence of symbols is assigned to represent the message as indicated at 128. The symbols are selected from a predefined set or alphabet of code symbols. In certain embodiments the symbol sequences are preassigned to corresponding predefined messages. When a message to be encoded is fixed, as in a station ID message, operations 120 and 128 preferably are combined to define a single invariant message symbol sequence.

[0049] Operation 124 assigns a plurality of substantially single-frequency code components to each of the message symbols. When the message is encoded, each symbol of the message is represented in the audio data by its corresponding plurality of substantially single-frequency code components. Each of such code components occupies only a narrow frequency band so that it may be distinguished from other such components as well as noise with a sufficiently low probability of error. It is recognized that the ability of an encoder or decoder to establish or resolve data in the frequency domain is limited, so that the substantially single-frequency components are represented by data within some finite or narrow frequency

band. Moreover, there are circumstances in which is advantageous to regard data within a plurality of frequency bands as corresponding to a substantially single-frequency component. This technique is useful where, for example, the component may be found in any of several adjacent bands due to frequency drift, variations in the speed of a tape or disk drive, or even as the result of an incidental or intentional frequency variation inherent in the design of a system.

[0050] Figures 2A through 2D illustrate first and second exemplary messages as specified by certain embodiments of the operations 120, 124 and 128 of Figure 2. Figure 2A illustrates a message symbol sequence A, B, C and D specified by operation 128 to encode a first exemplary message to be encoded, while Figure 2B illustrates a message symbol sequence J, K, L and M specified by operation 128 to encode a second exemplary message. Figure 2C is a table illustrating an exemplary assignment of four substantially single-frequency components to each of the symbols A, B, C and D. Depending on the application each of the symbols A, B, C and D is represented by a sufficient number of frequency components to insure a sufficiently low probability of error when the symbols are detected, which thus may be more or less than four such frequency components. In certain advantageous embodiments, the frequency components of the symbols A, B, C and D are selected from a predefined set of substantially single-frequency values $f_1, f_2, \ldots f_n$ (where n = 16 in this example) so that none of such values is included in more than one of the symbols A, B, C or D. This component assignment scheme provides a particularly effective means of distinguishing each of the symbols A, B, C, and D from all others in the first message. However, in certain other embodiments one or more components are shared among two or more of the symbols of the first message.

[0051] Figure 2D is a table illustrating an assignment of four substantially single-frequency components selected from the same predefined set $f_1, f_2, \ldots f_n$ as in Figure 2C to the second message symbols J, K, L and M. The frequencies assigned to each of the symbols J, K, L and M are selected from a predefined set so that no more than one substantially single-frequency

component included in any of the symbols J, K, L and M is also included in any of the symbols A, B, C and D. However, in certain other embodiments two or more substantially single-frequency components included in ones of the first message symbols are also included in ones of the second message symbols. Moreover, in certain advantageous embodiments, none of the frequency components assigned to any one of the symbols J, K, L and M is included in any other one of such symbols. Figure 2D illustrates such a frequency assignment scheme. However, in certain other embodiments one or more components are shared among two or more of the symbols of the second message.

[0052] In certain advantageous embodiments each of the symbols included in the first message has the same number of frequency components as each of the symbols in the second message. It will be seen from Figures 2C and 2D that by assigning the same number of frequency components to all of the symbols in both of the first and second messages, it is possible to optimize the reuse of frequency components between the symbols of the first and second messages, while maintaining complete frequency diversity among the symbols within each of the messages. It will also be seen from the foregoing that this technique which reuses frequency components in symbols of different messages enables the bandwidth of the ancillary data to be doubled when the two messages coexist along the time base of the audio data. In other embodiments, the number of frequency components included in each of the symbols of the first message differs from the number included in each of the second message symbols. In still others, at least two of the message symbols in the first and/or in the second message have differing numbers of frequency components. Moreover, in certain embodiments different numbers of components are included in different symbols of one or both messages.

[0053] In certain embodiments several further message parameters are selected singly or in combination in order to ensure that the first and second messages can be separately decoded. Block 132 represents multiple

operations which serve to determine parameters of the message to be encoded either to distinguish it from a message previously encoded in the audio data or from one or more further messages also being encoded therein at the same time. One such parameter is the symbol interval, selected in operation 140 of Figure 2. Figure 2E illustrates an example of how this operation can be carried out for distinguishing the first and second messages described above in connection with Figures 2A - 2D. In Figure 2E, as well as Figures 2F - 2I, the horizontal dimension represents the time base of the encoded audio data. In certain embodiments one of the first and second messages is already encoded in the audio data when it is received by the encoder. In certain ones of these embodiments, a decoder is included to decode the previously encoded message as an aid to setting the parameters of the message to be encoded. In other embodiments or in alternative modes of operation, both of the first and second messages are encoded in the audio data by the encoder. In this latter case, the received audio data may either be unencoded when received or previously encoded with a further message.

[0054] In Figure 2E, for the first message arranged in a message layer indicated at 21 the intervals for the message symbols A, B, C and D are selected as 0.5 second, while in the second message arranged in a message layer indicated at 24 the intervals for the message symbols J, K, L and M are selected as 0.3 second. By selecting the symbol intervals, as in this example, such that the symbol intervals in one message layer are not an integer multiple of the symbol intervals in the other the symbol intervals in the first and second messages are seldom aligned, so that the two messages are more readily detected separately. However, in other embodiments, different symbol intervals are selected and in some cases symbol intervals are provided for the first message which are integer multiples of symbol intervals in the second message.

[0055] In certain embodiments the intervals of symbols within one or both messages can overlap to provide even greater bandwidth. An example of such a message symbol arrangement effected by the operation 140 is

illustrated in Figure 2F, in which the symbols of the second message have a 50 percent overlap with the each of the following and preceding symbols. In the alternative, the symbols of one or more of the messages may be separated so that gaps are provided between the symbols thereof. An example of this encoding arrangement is provided in Figure 2G in which the symbols J, K, L and M are separated from one another by gaps 30 along the time base of the audio data.

[0056] Operation 144 of Figure 2 provides the ability to introduce an offset between the first and second messages to assist in distinguishing them especially in those embodiments in which the message durations and/or symbol intervals are the same. Figure 2H illustrates an example of encoding with an offset O between the first message 20 and a modified form of the second message J, X, K and L indicated at 34. Although not required in all applications, the second message includes a marker symbol X which has a fixed position in the message regardless of its informational content and is included through operation 136 in Figure 2. This enables the receiver/decoder 112 of Figure 1 to determine the times of occurrence of each of the symbols J, K and L. The marker symbol X, like the other symbols, comprises a combination of substantially single-frequency values selected from the predefined set thereof. Because the offset O between the two messages is fixed and known, it is used along with the marker symbol X by the receiver/decoder 112 in this example to locate the symbols A, B, C and D along the time base and detect them. In certain embodiments the offset O is used without reference to a marker symbol to separately detect the first and second messages.

[0057] Operation 148 of Figure 2 determines the duration of each of the messages, either in cooperation with operations 128 and 140 or by inserting padding data, as appropriate. Figure 2I illustrates an example of encoding two messages having differing message durations but in which the symbol intervals are the same in both messages. A modified first message 38 comprises the symbol sequence A, B and C, coexisting with the modified

second message 34 comprising the symbol sequence J, X, K and L. While the symbol intervals are the same in both messages, the differences in their overall durations enable the receiver/decoder 112 to readily distinguish the two messages.

[0058] Further advantageous message formatting techniques are disclosed in U.S. patent application No. 09/318, 045 filed May 25, 1999 in the names of Alan R. Neuhauser, Wendell D. Lynch and James M. Jensen, the entire contents of which are incorporated herein by reference.

[0059] FIGURE 3 is an overview of decoding processes and systems in accordance with certain embodiments of the invention using multiple buffers to decode multiple messages encoded in audio data.

[0060] In an operation 152 the encoded audio data is subjected to one or more processes to separate substantially single-frequency values for the various message symbol components potentially present in the audio data. When the audio data is received in analog form in the time domain (typically uncompressed data), these processes are advantageously carried out by transforming the analog audio data to digital audio data and transforming the latter to frequency domain data having sufficient resolution in the frequency domain to permit separation of the substantially single-frequency components of the potentially-present message symbols. A particularly advantageous implementation employs a fast Fourier transform to convert the data to the frequency domain and then produces signal-to-noise ratios for the substantially single-frequency symbol components that may be present. This implementation is disclosed in US Patent No. 5,764,763 to Jensen et al. which is incorporated by reference herein in its entirety. One advantage of the multiple message encoding processes described herein which reuse frequency components in the symbols of two or more coexisting messages, such as illustrated in Figures 2C and 2D, is the reduction of processing and storage requirements achieved by reducing the number of frequency components that must be detected. This also provides savings in

power usage, which is especially important in the case of portable decoders which draw their power from batteries.

[0061] When the audio data is received as time-domain digital data, it may be transformed into the frequency domain by any appropriate time-to-frequency domain transformation, as well as by filtering. In certain applications, analog audio data can be transformed into usable frequency domain data by analog filtering.

[0062] In an operation 156, the data representing the substantially single-frequency components is distributed to buffers n, n+1, n+2 . . . n+z each of which is dedicated to recovering a particular message encoded in the audio data formatted in a predetermined manner to conform to a respective message layer n, n+1, n+2, . . . n+z. In certain embodiments in which the same message in a given layer is repeated continuously in the audio data and is distinguishable from the messages of the other layers based on its uniquely different message length, the respective buffer dedicated to detecting the messages of this layer is arranged to provide a memory space having a length equal to the length of the message to be decoded.

[0063] The component data received by the buffer is stored in a predefined sequence of memory locations until the buffer is filled. Thereafter, the received data is added to the already-stored data values in sequence to accumulate corresponding message symbol components of the message to be detected which are separated in time by integer multiples of the message length. Accordingly, the frequency data of the message to be detected which are separated along the time base of the audio data by integer multiples of the message length are thus combined. Since they will necessarily represent the same symbol components of the message being decoded, they will accumulate to eventually present relatively high values for the components of each respective message symbol of the message being detected. If a message of the respective layer is present, the values stored in the buffer for the symbols of the message will increase with each new message interval,

while those of other messages having different message lengths, being misaligned with corresponding frequency values as accumulated in the buffer, will appear noise-like. After a sufficient number of messages have been accumulated in the buffer, the symbols of the desired message whose length conforms to the length of the buffer will stand out sufficiently to permit their identification in a respective operation 194, 198, 202 or 206. Advantageous techniques for interpreting such data are disclosed in U.S. patent application No. 09/948, 283 filed September 7, 2001 in the names of Ronald S. Kolessar and Alan R. Neuhauser, the entire contents of which are incorporated herein by reference.

[0064] A respective one of the buffers 176, 180, 184 and 190 is dedicated to decoding the messages of each layer. Accordingly, the length of the memory space in each of the buffers is selected to correspond to the length of the message potentially present in the respective message layer.

[0065] Where the messages of the various layers are distinguished by their different respective symbol intervals, the data in the buffers is analyzed for the presence of the respective components of the message symbols to be found in the corresponding message layer which persist for the known symbol interval and exhibit transitions to different message symbols at the boundaries of symbol intervals. This detection technique in certain embodiments is combined with an evaluation or utilization of additional distinguishing message parameters. In certain embodiments, this technique is used in combination with the technique disclosed above which relies on the presence of a distinctly different message length for the messages of each message layer.

[0066] In certain embodiments, the distinctly different symbol intervals are used together with the detection of marker symbols characteristic of the respective message layer and having fixed positions in each message, to determine the positions in time of the remaining symbol intervals for determining their identities based on the presence of their respective

frequency components within such intervals. In certain embodiments, differing symbol intervals between message layers are used along with a known time offset between the messages of each layer to detect the symbols of multiple layers, as well as to distinguish the symbols of one layer from those of another based on their time characteristics.

[0067] Where the messages in their respective layers are distinguished by a fixed offset between the messages, the detection of one or more symbols of any one or more message layers in the buffer data is used along with the known offset to determine the timing of the remaining symbols in both message layers. This timing data is used either to confirm the apparent symbol detections or to isolate symbol intervals for determining symbol identity based on the frequency components present in each symbol interval, or both.

[0068] Figure 4 is an overview of decoding processes and systems in certain embodiments using a single buffer. As in the embodiments of Figure 3, in an operation 210 the substantially single-frequency values for the various message symbol components potentially present in the audio data are separated therefrom. However, they are stored in a single buffer 214 from which the symbols constituting all of the messages present in the audio data, or which is desired to detect, are detected in an operation 218. From the detected symbols, the information content of the detected messages is extracted in an operation 222.

[0069] Figure 5 is an overview of various embodiments of a method of encoding two messages into audio data. First message data is translated to a first symbol sequence in block 226. Block 230 receives the first symbol sequence from block 226 as well as audio data introduced from another source. The audio data in block 230 is then encoded with the first symbol sequence. The symbol duration, message length, offset and/or frequency content of the first message/symbols are selected to ensure that the message

will be distinguishable from any and all other messages encoded or to be encoded in the audio data.

[0070] Block 230 then sends the encoded audio data to block 238. Second message data is introduced to block 234 and translated to a second symbol sequence. Block 234 sends the second symbol sequence to block 238. The audio data encoded with the first symbol sequence is then encoded with the second symbol sequence in block 238 so that at least some of the symbols of the second message coexist with at least some of the symbols of the first message along a time base of the audio data. As in the case of the first message, the symbol duration, message length, offset and/or frequency content of the second message/symbols in the second sequence are selected to ensure that the second message will be distinguishable from the first message as well as any and all other messages encoded in or to be encoded in the audio data. In certain embodiments the block 238 imposes a fixed offset between the first and second messages to facilitate their separate detection. Consequently, the encoded audio data leaving block 238 is encoded with two separately detectable and overlapping messages.

[0071] In certain embodiments, the encoder 238 is provided with two or more selectable encoding modes each providing an encoded message format differing from other formats available in other encoding modes in at least one of (1) message length, (2) symbol interval, (3) message offset, and (4) symbol frequency content. In certain ones of these embodiments, a detector 240 is provided for detecting either the first symbol sequence included in the audio data from encoder 230 or else its parameters or type of format. The detector 240 provides the detected information to the block 234 and/or block 238 where a message format is selected differing from that of the first message, by selecting at least one of (1) a different symbol interval or intervals than the first message, (2) a different message duration therefrom, (3) a time reference for the second message differing from that of the first, and (4) different combinations of frequency components for the second message symbols than for the first message symbols, to ensure that the first

and second messages can be detected separately. In certain embodiments, only one of these four formatting differences is selected to distinguish the second message from the first, while in others two or more are selected for this purpose. The ability to select the message format of the second message in this manner provides the encoder 238 with the ability to adapt to variable encoding environments. In embodiments used to encode a further message in broadcast audio, there may be circumstances in which an encoder at Network B receives a broadcast from Network A to be encoded with a message identifying Network B. Assuming that all network identification messages have a standard format, upon detection of an already-encoded message in the standard network format from Network A encoder 238 will select an alternative encoding format for its network identification message. The same capability can be used where a local station's encoder detects an already-encoded local station identification message in the audio data of a program to be encoded and broadcast.

[0072] FIGURE 6 illustrates various embodiments for encoding two messages into audio data by combining first and second symbol sequences representing first and second messages before encoding the symbol sequences into the audio data. First message data is introduced into block 242, which translates the data into a first symbol sequence including symbol component data representing the identity of the frequency components assigned to each symbol. Second message data is introduced into block 246, which translates the data into a second symbol sequence including data representing the identity of the frequency components assigned to each of its symbols.

[0073] The data produced in blocks 242 and 246 are sent to block 250 in which the first and second symbol sequences are combined to produce data representing all of the frequency components to be encoded in the audio data over its time base in order to encode the two messages therein. In certain embodiments in which the symbol sequence data is produced in digital form, the data representing the frequency components is OR'd to yield

combined data representing the totality of the frequency components to be encoded in the audio data to encode the two message sequences therein. The results of the combination of the first and second symbol sequences in block 250 are sent to block 254. Block 254 also receives audio data to be encoded with the first and second messages.

[0074] The data representing the frequency components to be encoded in the audio data over time controls the encoding process in block 254 to encode the first and second message sequences therein. Where the audio data to be encoded is received as frequency domain data, whether compressed or uncompressed, the data therein representing frequency components of the audio data corresponding to the symbol frequency components being encoded is selected and modified as needed to insert each of the symbol component frequencies therein. In certain embodiments, audio data received in compressed form is first uncompressed. Then one or more messages are encoded therein in accordance with any of the encoding techniques disclosed in this application. The audio data thus encoded is either re-compressed, or else output in uncompressed form.

[0075] FIGURE 7 is an overview of certain embodiments in which uncompressed time domain audio data is encoded with first and second messages. In certain ones of these embodiments of the audio data is received in digital form, while in others it is received in analog form. A memory 262 stores time domain data representing all of the frequency components of the symbols that may be included in either of the first or second messages. First and second message data specifying the symbols of the first and second messages is received in an addressing block 258 which responds thereto by sequentially reading out the time domain frequency component data required to represent the symbols of the first and second messages.

[0076] Audio data is received in blocks 266 and 382. The audio data sent to block 266 is analyzed for its ability to mask each of the symbol frequency components to be included in the audio data, which results in a set

of amplitude factors $A_1, A_2, \ldots A_n$ selected based on the audio data characteristics to ensure that the symbol frequency components to be encoded in the audio data will be maintained inaudible when the encoded audio data is reproduced acoustically. Various advantageous methods of evaluating the masking ability of audio data are disclosed in US Patent No. 5,764,763, incorporated herein in its entirety. The amplitude factors are applied to the assigned time-domain frequency components read from memory 262 in blocks 270 – 282. The assigned, inaudible, substantially single-frequency components from blocks 270 – 282 are mixed in block 286 from which the resulting mixed data is sent to block 382.

[0077] In block 382, the original audio data is encoded with the mixed data from block 286, for example, by adding the mixed data to the audio data. The output of block 382 is therefore audio data that is encoded with inaudible first and second messages whose symbols coexist in the time base of the audio data.

[0078] FIGURE 8 is an overview of a process for encoding two messages in audio data so that they repeat continuously and coexist therein along the time base of the audio data. Repeating encoded messages is an effective way to increase the reliability and accuracy of the encoding/decoding system and method, but since the messages are repeatedly encoded in the audio data as its frequency and amplitude characteristics vary over time, the magnitudes of the frequency components of the message symbols are adjusted to ensure that they remain inaudible in the reproduced audio data. Blocks 290 and 294 introduce the required substantially single-frequency components of the first and second message symbols, respectively, that will be encoded by the system. Block 298 loads new frequency domain audio data into the system for encoding and block 302 evaluates the masking ability of the new frequency domain audio data. Block 306 sets the parameters for the symbol components of the first and second messages based on the analysis in block 302 to produce current modifier data for use in modifying the frequency domain audio data to encode the first and second messages

therein while maintaining their inaudibility when the encoded audio data is reproduced acoustically. In block 310, the audio data is encoded with the first and second message and the encoded audio data is output in block 314. Block 318 determines if the loop should start again to continue encoding due to the introduction of new audio data.

[0079] FIGURE 9 is an overview of a process and system for encoding multiple messages in analog audio data, in which the messages comprise sequences of symbols each comprising a combination of substantially single-frequency components $f_0, f_1, \ldots f_{n-1}, f_n$ produced by analog generators 330, 334, . . . 338, 342. Analog audio data to be encoded is received in blocks 326 and 366. The audio data in block 326 is used to establish the masking requirements for the message symbol components to be added to the audio data. These masking requirements are sent to amplification factor control 346.

[0080] Two things happen in block 346. First the masking requirements are turned into amplification factors $A_0, A_1, \ldots A_n$, for adjusting the magnitudes of the components $f_0, f_1, \ldots f_n$. Secondly, the first and second message data is analyzed to determine which of the substantially single-frequency components produced by generators 330, 334, . . . 338 and 342 are to be encoded in the audio data at any given time. All other components (which thus are assigned to message symbols other than those being encoded at that time) are set to zero or any otherwise negligible level through adjustment of their respective amplification factors by the control 346. However, the control 346 assigns values to the amplification factors corresponding to the components to be encoded which will enable these components to be detected by an appropriate decoder while ensuring that they will be inaudible when the audio data is reproduced. Blocks 350 – 362 then adjust the amplitude levels of the substantially single-frequency components by using the amplitude factors produced in block 346. The outputs of blocks 350 – 362 are then sent to mixer 366 which encodes the components into the original analog audio data.

[0081] FIGURE 10 is a block diagram of an encoder employing a digital processor 370 operating in accordance with any of the digital encoding techniques described hereinabove. The processor receives audio data in any appropriate form, analog or digital, time domain or frequency domain, compressed or uncompressed. In the case of analog data, it is converted to digital form by the processor 370 for carrying out the encoding process. Parameters for one or more messages to be encoded, including message and symbol data, are stored in permanent storage 378 and retrieved therefrom by the processor 370 before encoding begins. The audio data, as well as temporary values produced by the processor in evaluating the masking capabilities of the audio data and symbol components to be encoded into the audio data, are stored temporarily in a main memory 374. Once the audio data has been encoded, it is output by the processor to be recorded, broadcast or otherwise utilized.

[0082] Although the invention has been described with reference to a particular arrangement of parts, features and the like, these are not intended to exhaust all possible arrangements or features, and indeed many other modification and variation will be ascertainable to those of skill in the art.

What is claimed is:

1. A method of encoding audio data with a message, the audio data having a preexisting message encoded therein comprising a sequence of preexisting message symbols in a first format, the preexisting message symbols each comprising a combination of substantially single-frequency components having frequencies selected from a predefined set of substantially single-frequency values, comprising:

providing data defining a plurality of further message symbols each comprising a combination of substantially single-frequency components selected from a predefined set of substantially single-frequency values; and

encoding the audio data with a further message comprising a sequence of the further message symbols in a second format differing from the first format, such that at least some of the further message symbols of the further message coexist with at least some of the preexisting message symbols of the preexisting message along a time base of the audio data.

2. The method of claim 1, wherein at least some of the substantially single-frequency components included in the further message symbols have the same frequency as at least some of the substantially single-frequency components included in the preexisting message symbols.

3. The method of claim 1, wherein the combination of the substantially single-frequency components of each preexisting message symbol is present in the audio data for a predefined symbol interval within the time base of the audio data, and

wherein the further message is encoded in the second format within the time base of the audio data so that:

(a) the further message symbols have symbol intervals differing from the symbol intervals of the preexisting message symbols;

(b) the further message has a time offset with respect to the preexisting message; and/or

(c) the further message has a duration differing from a duration of the preexisting message.

4. The method of claim 3, wherein the further message as encoded is arranged within the time base of the audio data so that the further message symbols have symbol intervals differing from the symbol intervals of the preexisting message symbols.

5. The method of claim 4, wherein the symbol intervals of the further message symbols overlap within the time base of the audio data.

6. The method of claim 4, wherein the symbol intervals of the further message symbols are spaced apart within the time base of the audio data.

7. The method of claim 4, wherein the lengths of the symbol intervals of the preexisting message symbols and the symbol intervals of the further message symbols are not integer multiples of each other within the time base of the audio data.

8. The method of claim 3, wherein the further message as encoded is arranged within the time base of the audio data so that the further message has a time offset with respect to the preexisting message.

9. The method of claim 8, wherein the durations of the preexisting message and of the further message are substantially the same.

10. The method of claim 3, wherein the further message as encoded is arranged within the time base of the audio data so that the further message has a duration differing from a duration of the preexisting message.

11. The method of claim 10, wherein the symbol intervals of the preexisting message symbols and the further message symbols are substantially the same.

12. The method of claim 11, wherein at least some of the substantially single-frequency components included in the further message symbols have the same frequency as at least some of the substantially single-frequency components included in the preexisting message symbols.

13. The method of claim 1, wherein the audio data to be encoded with a message comprises compressed frequency domain data and encoding the audio data comprises modifying portions of the frequency domain data corresponding to the substantially single-frequency components.

14. The method of claim 1, further comprising detecting at least one of the preexisting message and the further message.

15. The method of claim 1, further comprising:

detecting the first format of the preexisting message symbols; and

selecting the second format of the further message symbols based on the detected first format.

16. The method of claim 15, wherein the preexisting message symbols have first symbol intervals along the time base of the audio data, and the preexisting message has a predetermined duration and a predetermined time reference on the time base of the audio data; and selecting the second format comprises at least one of (a) selecting second symbol intervals for the further message symbols differing from the first symbol intervals, (b) selecting a second message duration for the further message differing from the predetermined duration of the preexisting message, (c) selecting a further message time reference for the further message on the time base of the audio data differing from the predetermined time reference of the preexisting message, and (d) selecting the combinations of the substantially single-

frequency components of the further message symbols so that they differ from the combinations of the preexisting message symbols.

17. The method of claim 16, wherein selecting the second format comprises selecting second symbol intervals for the further message symbols differing from the first symbol intervals.

18. The method of claim 16, wherein selecting the second format comprises selecting a second message duration for the second message differing from the predetermined duration of the preexisting message.

19. The method of claim 16, wherein selecting the second format comprises selecting a further message time reference for the further message on the time base of the audio data differing from a predetermined time reference of the pre-existing message.

20. The method of claim 16, wherein selecting the second format comprises selecting the combinations of the substantially single-frequency components of the further message symbols so that they differ from the combinations of the preexisting message symbols.

21. A method of encoding audio data with first and second messages each comprising a sequence of first and second message symbols, respectively, comprising:

providing data defining the first and second message symbols to comprise a combination of substantially single-frequency values selected from a predefined set of substantially single-frequency values;

encoding the audio data with the sequence of first message symbols of the first message in a first format; and

encoding the audio data with the sequence of second message symbols of the second message in a second format differing from the first format, such that at least some of the first message symbols of the first

message co-exist with at least some of the second message symbols of the second message along a time base of the audio data.

22. The method of claim 21, wherein at least some of the substantially single-frequency components included in the first message symbols have the same frequency of at least some of the substantially single-frequency components included in the second message symbols.

23. The method of claim 21, wherein the sequences of first and second message symbols are encoded with their respective first and second formats within the time base of the audio data so that:

(a) the first message symbols have symbol intervals differing from symbol intervals of the second message symbols;

(b) the first message has a time offset with respect to the second message; and/or

(c) the first message has a duration differing from the duration of the second message.

24. The method of claim 23, wherein the first message as encoded is arranged within the time base of the audio data so that the first message symbols have symbol intervals differing from the symbol intervals of the second message symbols.

25. The method of claim 24, wherein the symbol intervals of the first message symbols overlap within the time base of the audio data.

26. The method of claim 24, wherein the symbol intervals of the first message symbols are spaced apart within the time base of the audio data.

27. The method of claim 24, wherein the symbol intervals of the first message symbols are not integer multiples of the symbol intervals of the second message symbols within the time base of the audio data.

28. The method of claim 23, wherein the first message as encoded is arranged within the time base of the audio data so that the first message has a time offset with respect to the second message.

29. The method of claim 28, wherein the durations of the first and second messages are substantially the same.

30. The method of claim 23, wherein the first message as encoded is arranged within the time base of the audio data so that the first message has a duration differing from a duration of the second message.

31. The method of claim 30, wherein the symbol intervals of the first and second message symbols are substantially the same.

32. The method of claim 23, wherein at least some of the substantially single-frequency components included in the first message symbols have the same frequency as at least some of the substantially single-frequency components included in the second message symbols.

33. The method of claim 21, wherein the audio data to be encoded comprises compressed frequency domain data and encoding the audio data comprises modifying portions of the frequency domain data corresponding to the substantially single-frequency components.

34. The method of claim 21, further comprising detecting at least one of the first and second messages.

35. A method of detecting a first message and a second message encoded in audio data as a sequence of first and second message symbols, respectively, at least some of the first message symbols coexisting with at least some of the second message symbols along a time base of the audio data, each of the first and second message symbols comprising a combination of substantially single-frequency components having frequencies selected from a predefined set of substantially single-frequency values, the first sequence of message symbols having a first format and the second

sequence of message symbols having a second format differing from the the first format, comprising:

detecting the first message symbols based on the first format thereof; and

detecting the second message symbols based on the second format thereof.

36. The method of claim 35, wherein the first format of the first sequence of message symbols and the second format of the second sequence of message symbols differ in at least one of (a) differing message symbol intervals along the time base of the audio data, (b) differing message lengths along the time base of the audio data, and (c) an offset of the first message from the second message along the time base of the audio data;

wherein detecting the first and second message symbols is based on at least one of differing message symbol intervals of the first and second messages, differing message lengths of the first and second messages and an offset of the first message from the second message along the time base of the audio data.

37. The method of claim 36, wherein detecting the first and second messages comprises producing frequency data representing substantially single-frequency values of the audio data over its time base and examining the frequency data to detect the first and second message symbols therein.

38. The method of claim 37, wherein the first and second messages are repeated periodically in the audio data over its time base and the first and second messages have different respective message lengths,

wherein detecting the first message comprises storing the frequency data in a first memory space such that frequency data separated along the time base of the audio data by an integer multiple of the message length of the first message are combined in the first memory space and examining the

combined frequency data in the first memory space to detect the first message symbols therein, and

wherein detecting the second message comprises storing the frequency data in a second memory space such that frequency data separated along the time base of the audio data by an integer multiple of the message length of the second message are combined in the second memory space and examining the combined frequency data in the second memory space to detect the second message symbols therein.

39. The method of claim 38, wherein the frequency data are combined in the first and second memory spaces by adding values thereof separated along the time base of the audio data by an integer multiple of the first and second message lengths.

40. The method of claim 36, wherein the first and second messages have respectively different message symbol intervals and detecting the first and second message symbols comprises detecting the first and second message symbols based on their respectively different symbol intervals.

41. The method of claim 36, wherein the first and second messages have respectively different message lengths and detecting the first and second message symbols comprises detecting the first and second message symbols based on the respectively different message lengths of the first and second messages.

42. The method of claim 36, wherein the first and second messages are offset along the time base of the audio data and detecting the first and second message symbols comprises detecting the first and second message symbols based on the offset of the first and second messages.

43. The method of claim 36, wherein at least some of the substantially single-frequency components included in the first message symbols have the

same frequency as at least some of the substantially single-frequency components included in the second message symbols;

wherein detecting the first message symbols comprises detecting the substantially single-frequency components of the first message symbols, including the substantially single-frequency components thereof having the same frequency as components included in the second message symbols; and

detecting the second message symbols comprises detecting the substantially single-frequency components of the second message symbols, including the substantially single-frequency components thereof having the same frequency as components included in the first message symbols.

44. A system for encoding audio data with a message, the audio data having a preexisting message encoded therein comprising a sequence of preexisting message symbols in a first format, the preexisting message symbols each comprising a combination of substantially single-frequency components having frequencies selected from a predefined set of substantially single-frequency values, comprising:

means for providing data defining a plurality of further message symbols each comprising a combination of substantially single-frequency components selected from a predefined set of substantially single-frequency values; and

means for encoding the audio data with a further message comprising a sequence of the further message symbols in a second format differing from the first format, such that at least some of the further message symbols of the further message coexist with at least some of the preexisting message symbols of the preexisting message along a time base of the audio data.

45. The system of claim 44, wherein the means for encoding is operative to encode at least one of the further message symbols so that it includes at least one substantially single-frequency component having the same frequency as at least one of the substantially single-frequency components included in the preexisting message symbols.

46. The system of claim 44, wherein the combination of the substantially single-frequency components of each preexisting message symbol is present in the audio data for a predefined symbol interval within the time base of the audio data, and

wherein the means for encoding is operative to encode the further message in the second format within the time base of the audio data so that:

(a) the further message symbols have symbol intervals differing from the symbol intervals of the preexisting message symbols;

(b) the further message has a time offset with respect to the preexisting message; and/or

(c) the further message has a duration differing from a duration of the preexisting message.

47. The system of claim 46, wherein the means for encoding is operative to encode the further message within the time base of the audio data so that the further message symbols have symbol intervals differing from the symbol intervals of the preexisting message symbols.

48. The system of claim 47, wherein the symbol intervals of the further message symbols overlap within the time base of the audio data.

49. The system of claim 47, wherein the symbol intervals of the further message symbols are spaced apart within the time base of the audio data.

50. The system of claim 47, wherein the lengths of the symbol intervals of the preexisting message symbols and the symbol intervals of the further message symbols are not integer multiples of each other within the time base of the audio data.

51. The system of claim 46, wherein the further message as encoded is arranged within the time base of the audio data so that the further message has a time offset with respect to the preexisting message.

52. The system of claim 51, wherein the durations of the preexisting message and of the further message are substantially the same.

53. The system of claim 46, wherein the means for encoding is operative to encode the further message within the time base of the audio data so that the further message has a duration differing from a duration of the preexisting message.

54. The system of claim 53, wherein the symbol intervals of the preexisting message symbols and the further message symbols are substantially the same.

55. The system of claim 46, wherein at least some of the substantially single-frequency components included in the further message symbols have the same frequency as at least some of the substantially single-frequency components included in the preexisting message symbols.

56. The system of claim 44, wherein the audio data to be encoded with a message comprises compressed frequency domain data and the means for encoding is operative to encode the audio data by modifying portions of the frequency domain data corresponding to the substantially single-frequency components.

57. The system of claim 44, further comprising means for detecting at least one of the preexisting message and the further message.

58. The system of claim 44, further comprising:

means for detecting the first format of the preexisting message symbols; and

means for selecting the second format of the further message symbols based on the detected first format.

59. The system of claim 58, wherein the preexisting message symbols have first symbol intervals along the time base of the audio data, and the preexisting message has a predetermined duration and a predetermined time reference on the time base of the audio data; and the means for selecting the second format is operative to carry out at least one of (a) selecting second symbol intervals for the further message symbols differing from the first symbol intervals, (b) selecting a second message duration for the further message differing from the predetermined duration of the preexisting message, (c) selecting a further message time reference for the further message on the time base of the audio data differing from the predetermined time reference of the preexisting message, and (d) selecting the combinations of the substantially single-frequency components of the further message symbols so that they differ from the combinations of the preexisting message symbols.

60. The system of claim 59, wherein the means for selecting the second format is operative to select second symbol intervals for the further message symbols differing from the first symbol intervals.

61. The system of claim 59, wherein the means for selecting the second format is operative to select a second message duration for the second message differing from the predetermined duration of the preexisting message.

62. The system of claim 59, wherein the means for selecting the second format is operative to select a further message time reference for the further

message on the time base of the audio data differing from a predetermined time reference of the pre-existing message.

63. The system of claim 59, wherein the means for selecting the second format is operative to select the combinations of the substantially single-frequency components of the further message symbols so that they differ from the combinations of the preexisting message symbols.

64. A system for encoding audio data with first and second messages each comprising a sequence of first and second message symbols, respectively, comprising:

means for providing data defining the first and second message symbols to comprise a combination of substantially single-frequency values selected from a predefined set of substantially single-frequency values; and

means for encoding the audio data with the sequence of first message symbols of the first message in a first format and for encoding the audio data with the sequence of second message symbols of the second message in a second format differing from the first format, such that at least some of the first message symbols of the first message co-exist with at least some of the second message symbols of the second message along a time base of the audio data.

65. The system of claim 64, wherein the means for encoding is operative to encode at least one of the first message symbols so that it includes at least one substantially single-frequency component having the same frequency as at least one of the substantially single-frequency components included in the second message symbols.

66. The system of claim 64, wherein the means for encoding is operative to encode the sequences of first and second message symbols with their respective first and second formats within the time base of the audio data so that:

(a) the first message symbols have symbol intervals differing from symbol intervals of the second message symbols;

(b) the first message has a time offset with respect to the second message; and/or

(c) the first message has a duration differing from the duration of the second message.

67. The system of claim 66, wherein the means for encoding is operative to encode the first message within the time base of the audio data so that the first message symbols have symbol intervals differing from the symbol intervals of the second message symbols.

68. The system of claim 67, wherein the symbol intervals of the first message symbols overlap within the time base of the audio data.

69. The system of claim 67, wherein the symbol intervals of the first message symbols are spaced apart within the time base of the audio data.

70. The system of claim 67, wherein the symbol intervals of the first message symbols are not integer multiples of the symbol intervals of the second message symbols within the time base of the audio data.

71. The system of claim 66, wherein the means for encoding is operative to encode the first message within the time base of the audio data so that the first message has a time offset with respect to the second message.

72. The system of claim 71, wherein the durations of the first and second messages are substantially the same.

73. The system of claim 66, wherein the means for encoding is operative to encode the first message within the time base of the audio data so that the first message has a duration differing from a duration of the second message.

74. The system of claim 73, wherein the symbol intervals of the first and second message symbols are substantially the same.

75. The system of claim 66, wherein at least some of the substantially single-frequency components included in the first message symbols have the same frequency as at least some of the substantially single-frequency components included in the second message symbols.

76. The system of claim 64, wherein the audio data to be encoded comprises compressed frequency domain data and the means for encoding the audio data is operative to modify portions of the frequency domain data corresponding to the substantially single-frequency components.

77. The system of claim 64, further comprising means for detecting at least one of the first and second messages.

78. A system for detecting a first message and a second message encoded in audio data as a sequence of first and second message symbols, respectively, at least some of the first message symbols coexisting with at least some of the second message symbols along a time base of the audio data, each of the first and second message symbols comprising a combination of substantially single-frequency components having frequencies selected from a predefined set of substantially single-frequency values, the first sequence of message symbols having a first format and the second sequence of message symbols having a second format differing from the first format, comprising:

means for detecting the first message symbols based on the first format thereof and for detecting the second message symbols based on the second format thereof.

79. The system of claim 78, wherein the first format of the first sequence of message symbols and the second format of the second sequence of message symbols differ in at least one of (a) differing message symbol intervals along

the time base of the audio data, (b) differing message lengths along the time base of the audio data, and (c) an offset of the first message from the second message along the time base of the audio data;

wherein the means for detecting the first and second message symbols is operative to detect the first and second message symbols based on at least one of differing message symbol intervals of the first and second messages, differing message lengths of the first and second messages and an offset of the first message from the second message along the time base of the audio data.

80. The system of claim 79, wherein means for detecting the first and second messages is operative to produce frequency data representing substantially single-frequency values of the audio data over its time base and examining the frequency data to detect the first and second message symbols therein.

81. The system of claim 80, wherein the first and second messages are repeated periodically in the audio data over its time base and the first and second messages have different respective message lengths, and

wherein the means for detecting the first message symbols and the second message symbols is operative to store the frequency data in a first memory space such that frequency data separated along the time base of the audio data by an integer multiple of the message length of the first message are combined in the first memory space and to examine the combined frequency data in the first memory space to detect the first message symbols therein, and to store the frequency data in a second memory space such that frequency data separated along the time base of the audio data by an integer multiple of the message length of the second message are combined in the second memory space and to examine the combined frequency data in the second memory space to detect the second message symbols therein.

82. The system of claim 81, wherein the frequency data are combined in the first and second memory spaces by adding values thereof separated along the time base of the audio data by an integer multiple of the first and second message lengths.

83. The system of claim 79, wherein the first and second messages have respectively different message symbol intervals and the means for detecting the first and second message symbols comprises means for detecting the first and second message symbols based on their respectively different symbol intervals.

84. The system of claim 79, wherein the first and second messages have respectively different message lengths and the means for detecting the first and second message symbols comprises means for detecting the first and second message symbols based on the respectively different message lengths of the first and second messages.

85. The system of claim 79, wherein the first and second messages are offset along the time base of the audio data and detecting the first and second message symbols comprises detecting the first and second message symbols based on the offset of the first and second messages.

86. The system of claim 79, wherein at least some of the substantially single-frequency components included in the first message symbols have the same frequency as at least some of the substantially single-frequency components included in the second message symbols; and

wherein the means for detecting the first message symbols and the second message symbols is operative to detect the substantially single-frequency components of the first message symbols, including the substantially single-frequency components thereof having the same frequency as components included in the second message symbols and to detect the substantially single-frequency components of the second message symbols,

including the substantially single-frequency components thereof having the same frequency as components included in the first message symbols.

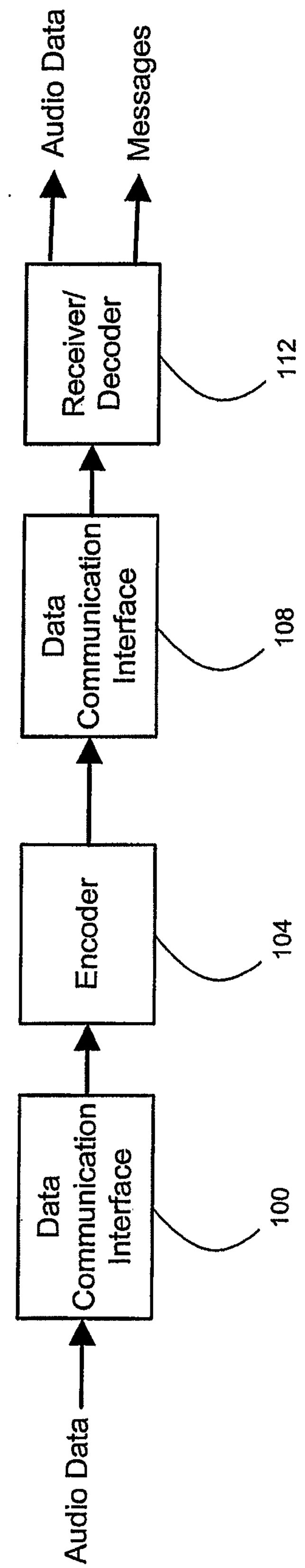

Audio Data
Data Communication Interface
100
Encoder
104
Data Communication Interface
108
Receiver/ Decoder
112
Audio Data
Messages

FIGURE 1

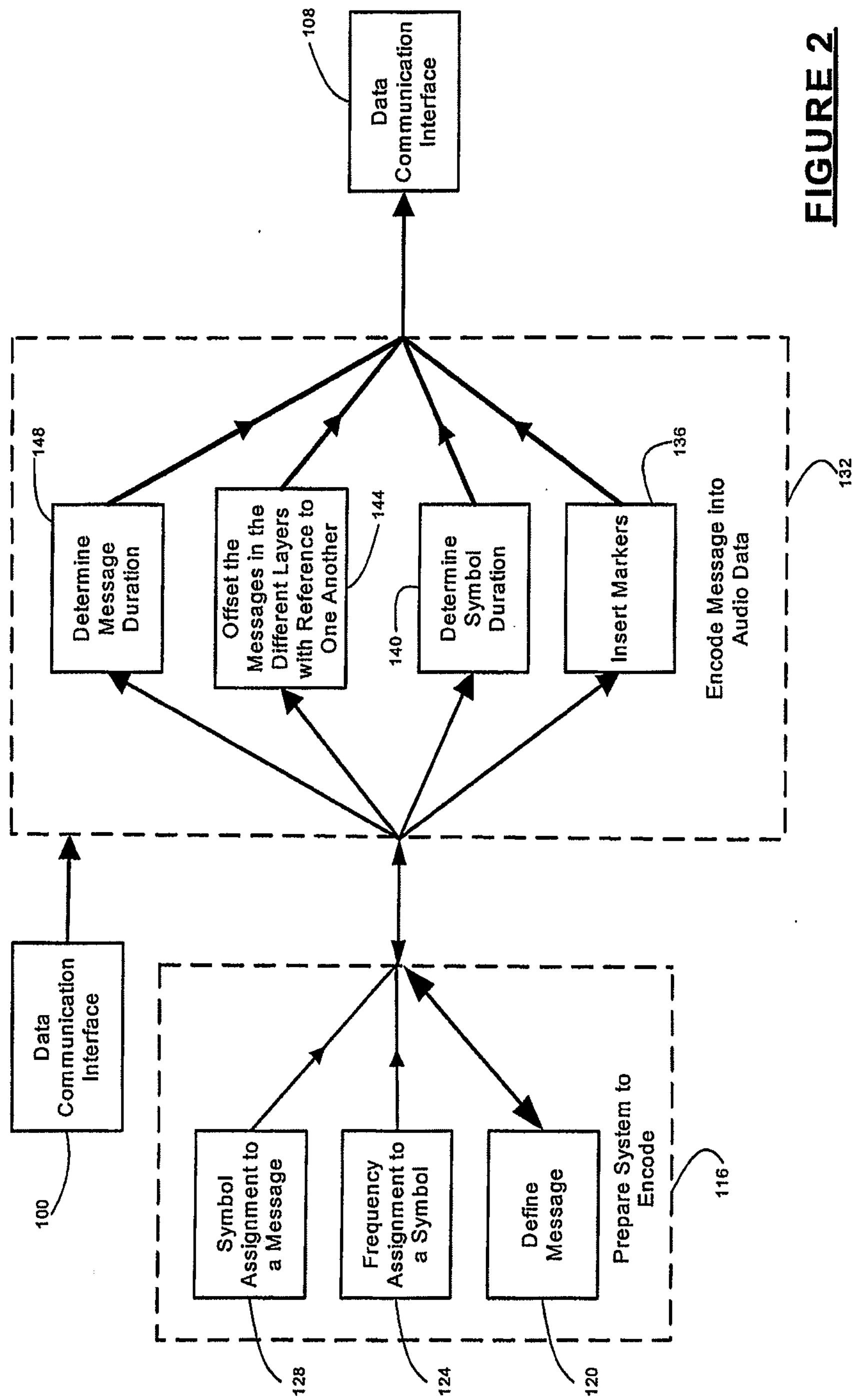

Data Communication Interface
100
Symbol Assignment to a Message
128
Frequency Assignment to a Symbol
124
Define Message
120
Prepare System to Encode
116
Determine Message Duration
148
Offset the Messages in the Different Layers with Reference to One Another
144
Determine Symbol Duration
140
Insert Markers
136
Encode Message into Audio Data
132
Data Communication Interface
108

FIGURE 2

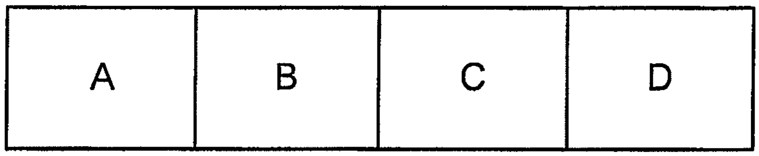


FIGURE 2A

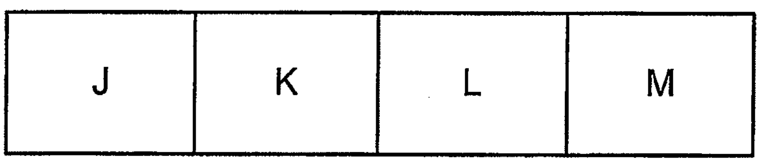


FIGURE 2B

A	B	C	D
f_1	f_2	f_3	f_4
f_5	f_6	f_7	f_8
f_9	f_{10}	f_{11}	f_{12}
f_{13}	f_{14}	f_{15}	f_{16}

FIGURE 2C

J	K	L	M
f_1	f_2	f_3	f_4
f_6	f_7	f_8	f_5
f_{11}	f_{12}	f_9	f_{10}
f_{16}	f_{13}	f_{14}	f_{15}

FIGURE 2D

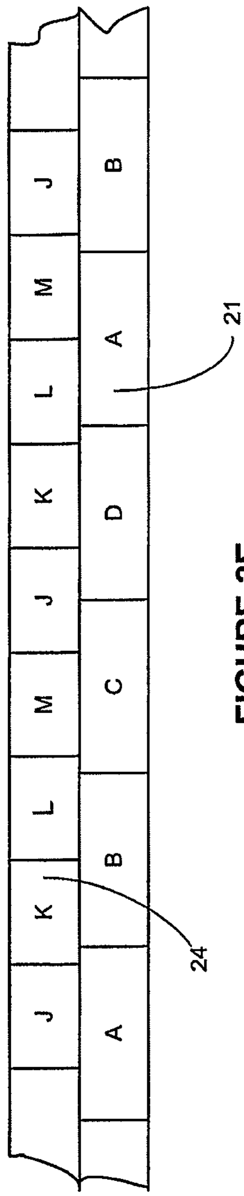


FIGURE 2E

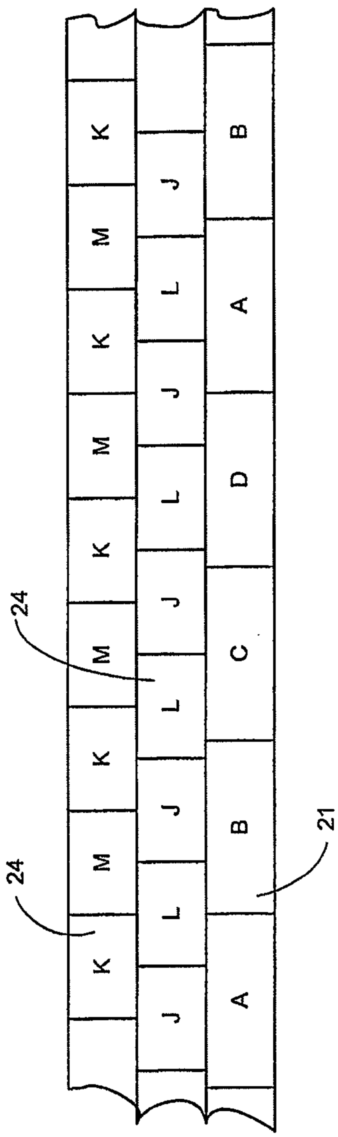


FIGURE 2F

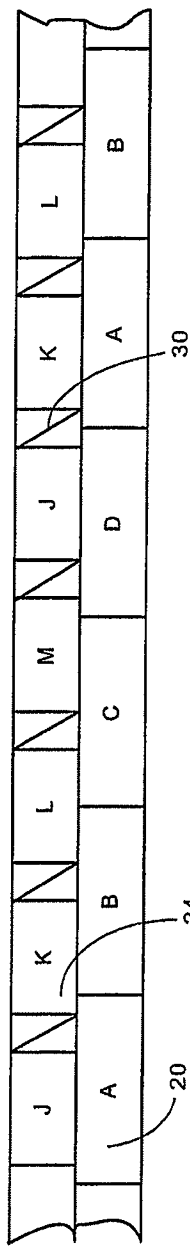


FIGURE 2G

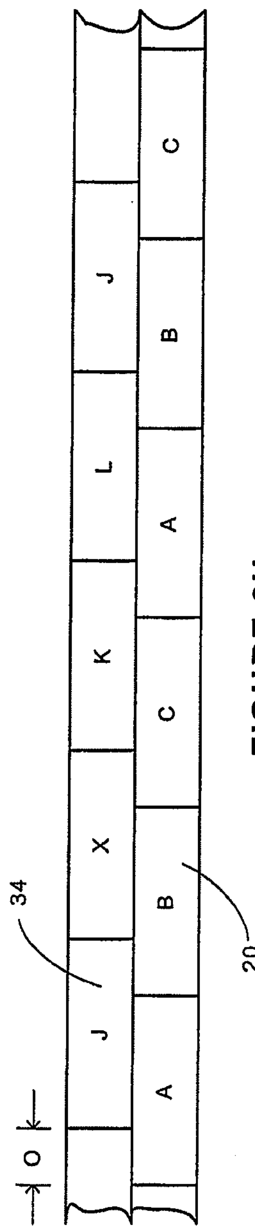


FIGURE 2H

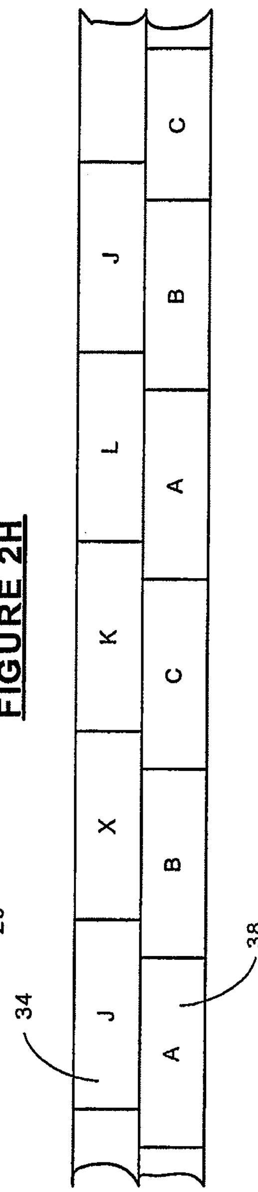


FIGURE 2I

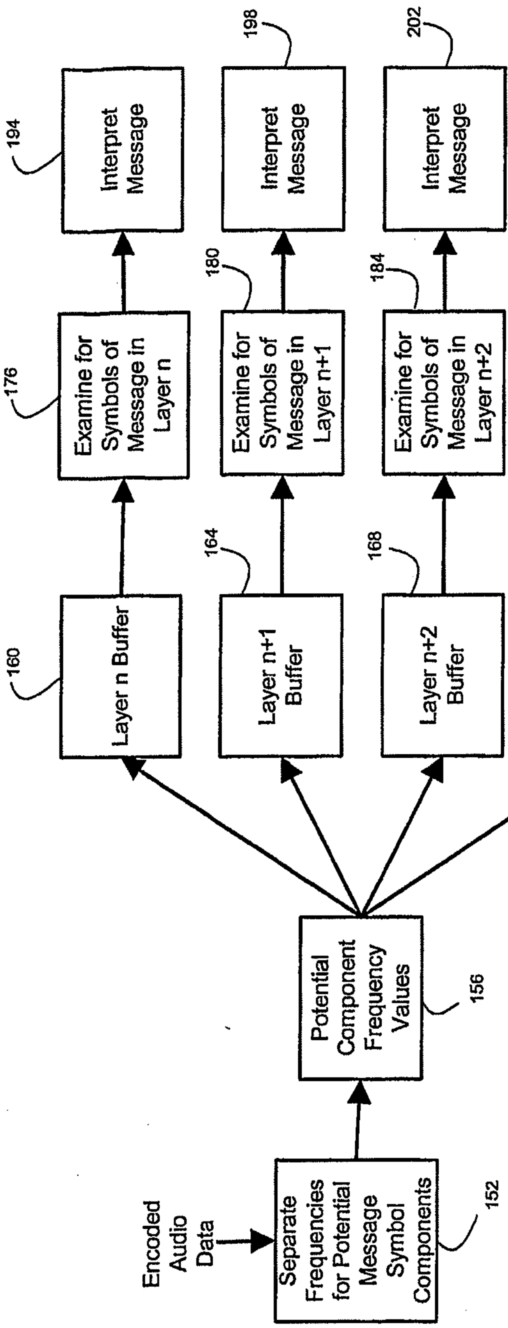


FIGURE 3

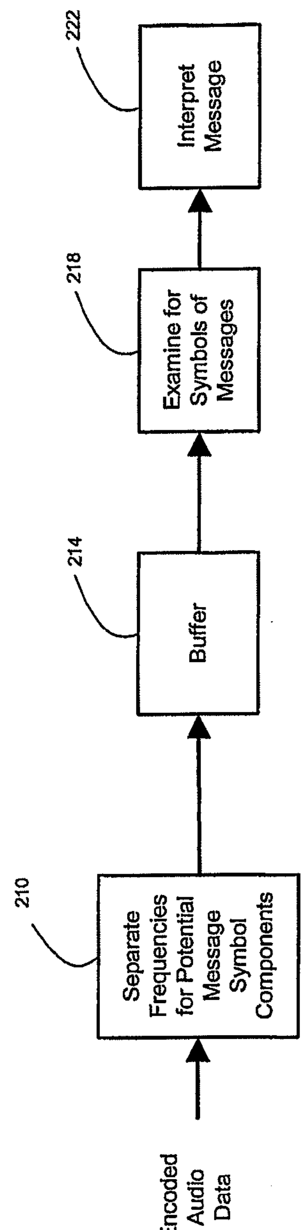


FIGURE 4

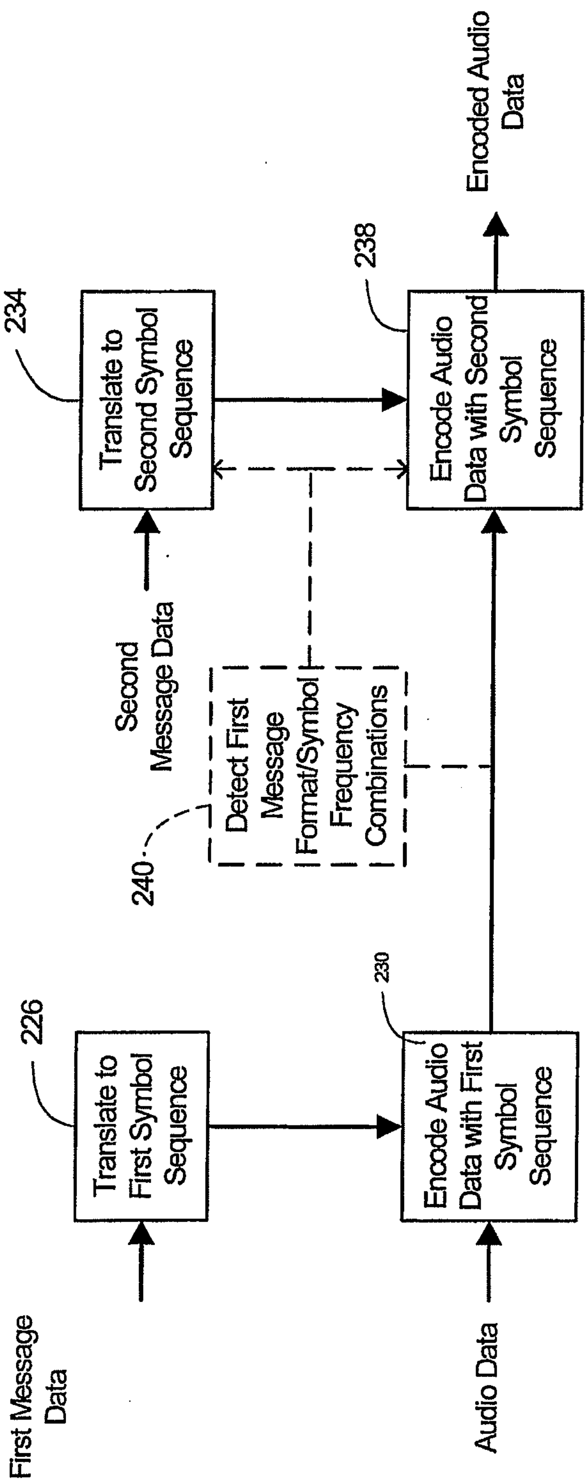

First Message Data
Translate to First Symbol Sequence
226
Audio Data
Encode Audio Data with First Symbol Sequence
230
Detect First Message Format/Symbol Frequency Combinations
240
Second Message Data
Translate to Second Symbol Sequence
234
Encode Audio Data with Second Symbol Sequence
238
Encoded Audio Data

FIGURE 5

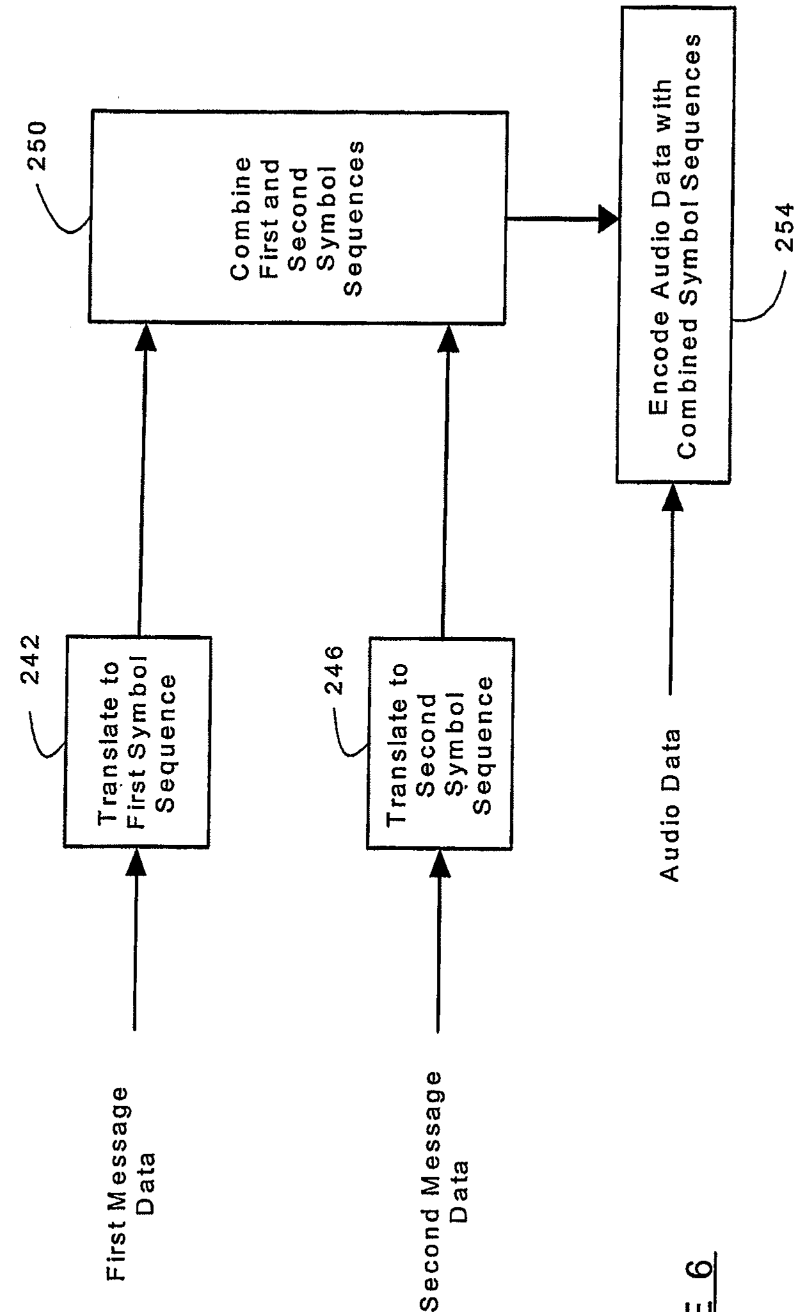

First Message Data
Translate to First Symbol Sequence
242
Second Message Data
Translate to Second Symbol Sequence
246
Combine First and Second Symbol Sequences
250
Audio Data
Encode Audio Data with Combined Symbol Sequences
254

FIGURE 6

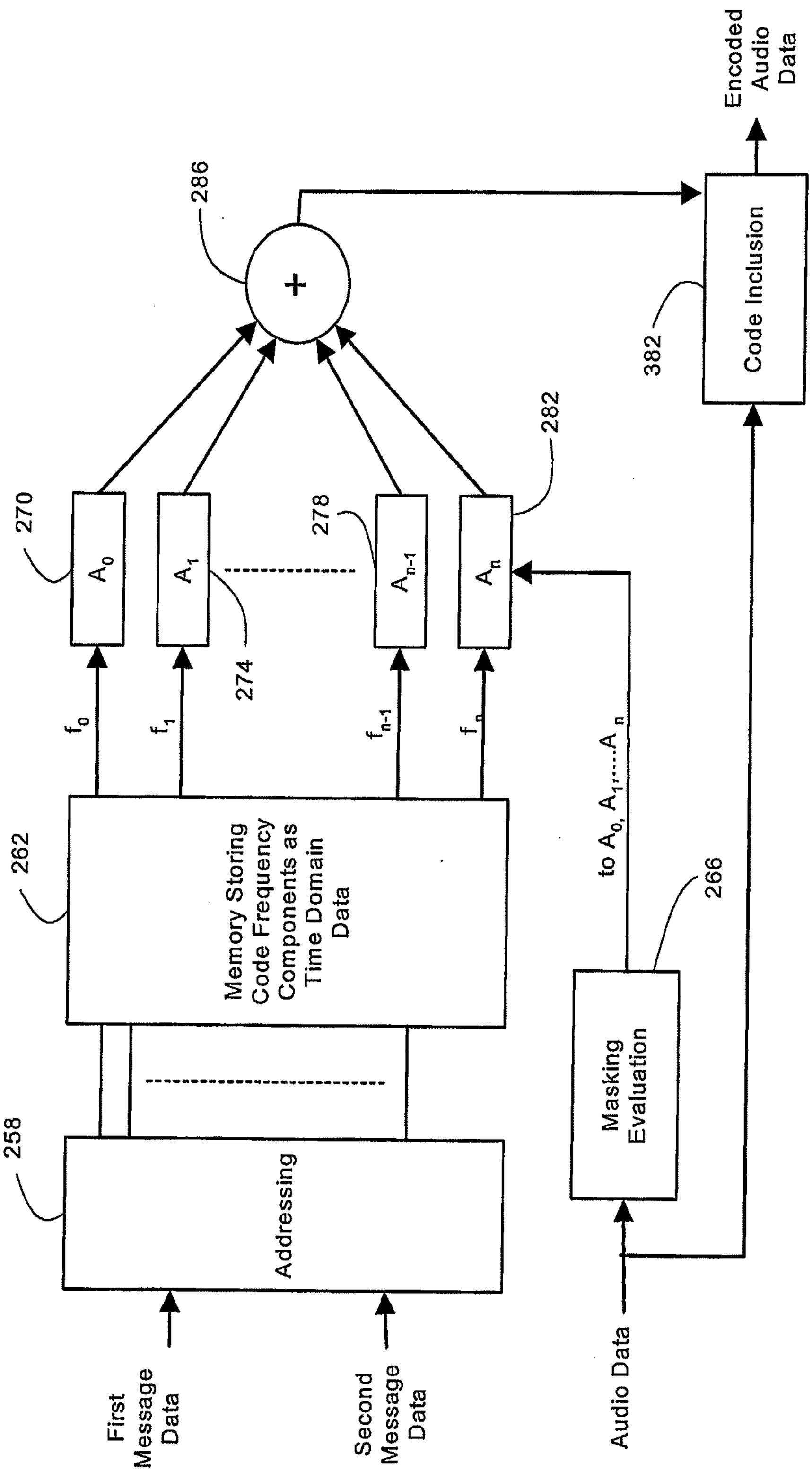

First Message Data
Second Message Data
Addressing
258
Memory Storing Code Frequency Components as Time Domain Data
262
f_0
f_1
f_{n-1}
f_n
A_0
A_1
A_{n-1}
A_n
270
274
278
282
286
+
Audio Data
Masking Evaluation
266
to $A_0, A_1, \ldots A_n$
Code Inclusion
382
Encoded Audio Data

FIGURE 7

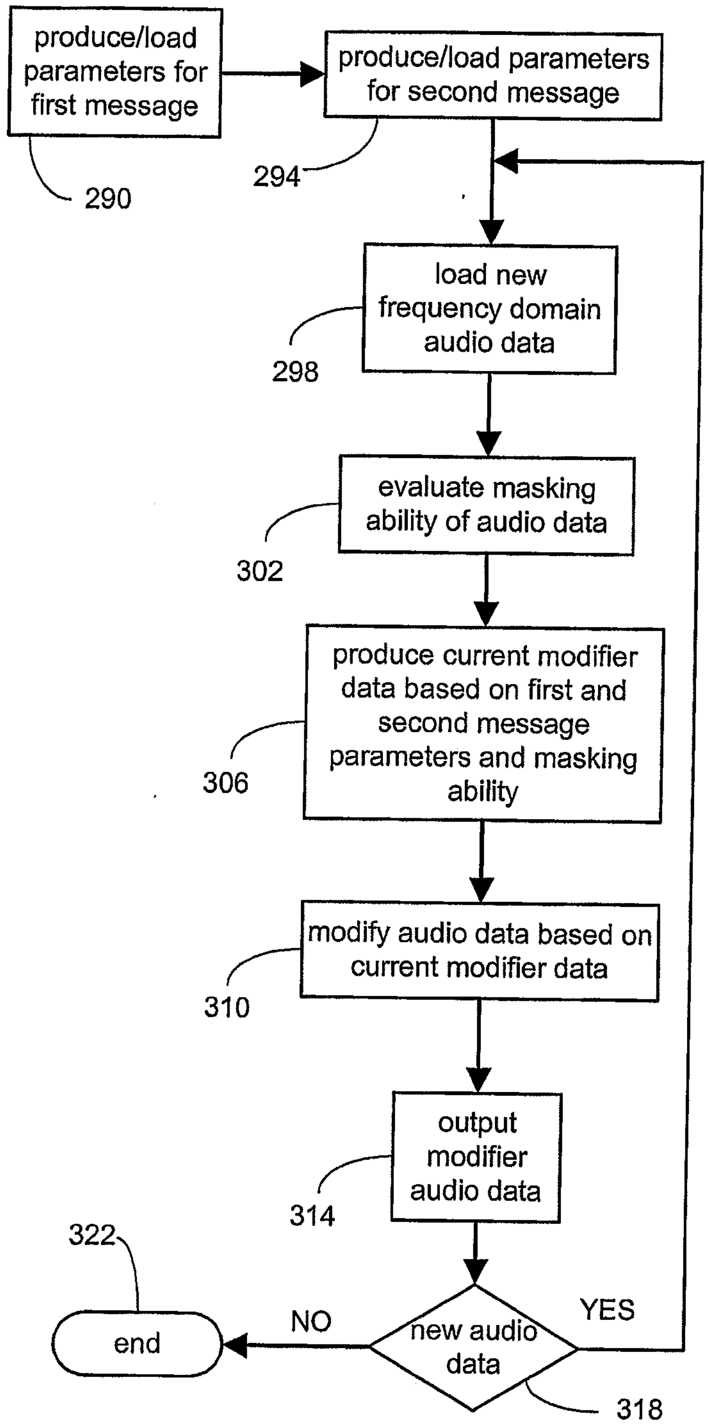

produce/load parameters for first message
produce/load parameters for second message
290
294
load new frequency domain audio data
298
evaluate masking ability of audio data
302
produce current modifier data based on first and second message parameters and masking ability
306
modify audio data based on current modifier data
310
output modifier audio data
314
322
end
NO
new audio data
YES
318

FIGURE 8

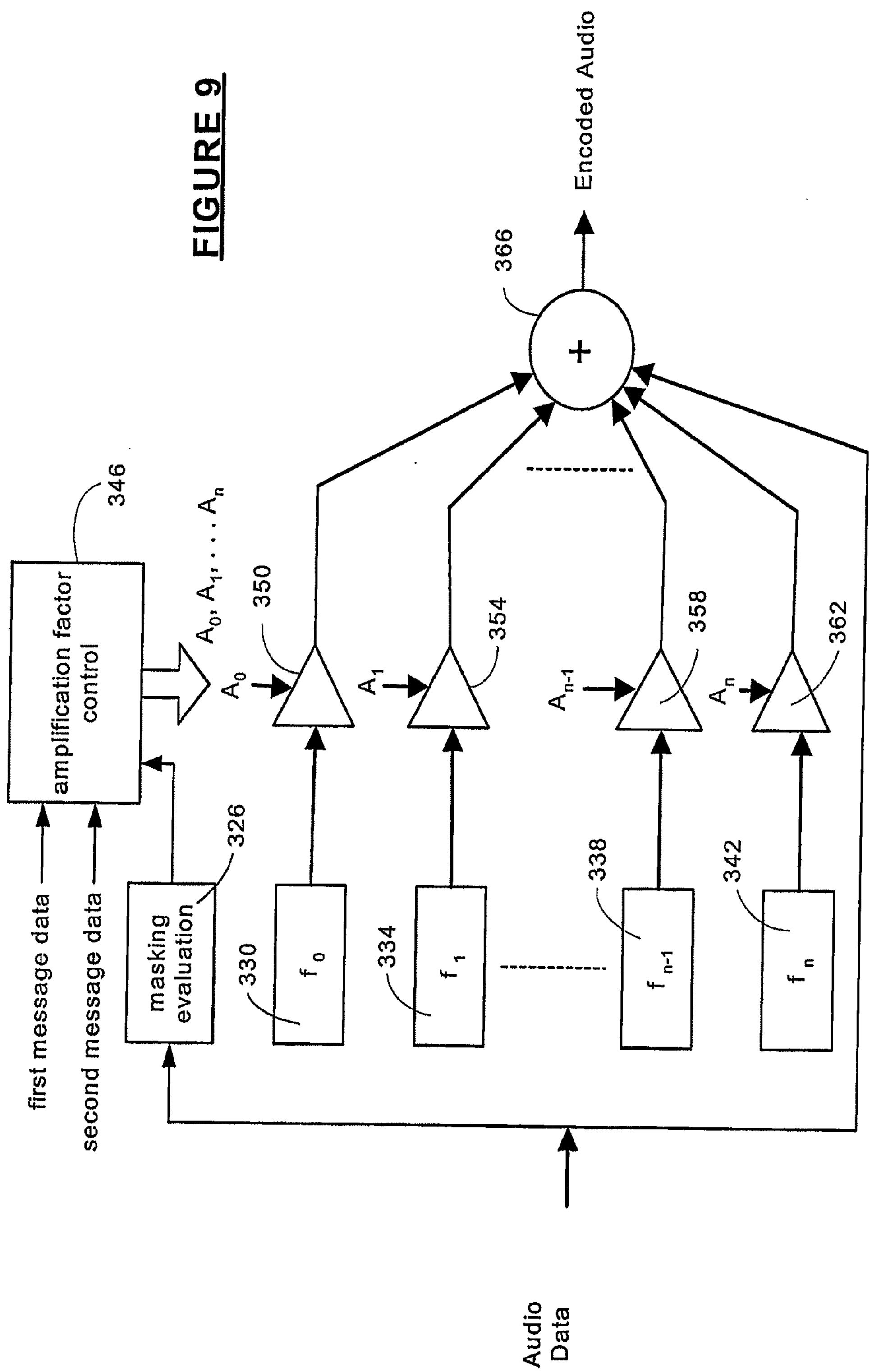

Encoded Audio
366
+
346
amplification factor control
$A_0, A_1, \ldots A_n$
350
354
358
362
A_0
A_1
A_{n-1}
A_n
first message data
second message data
326
masking evaluation
330
f_0
334
f_1
338
f_{n-1}
342
f_n
Audio Data

FIGURE 9

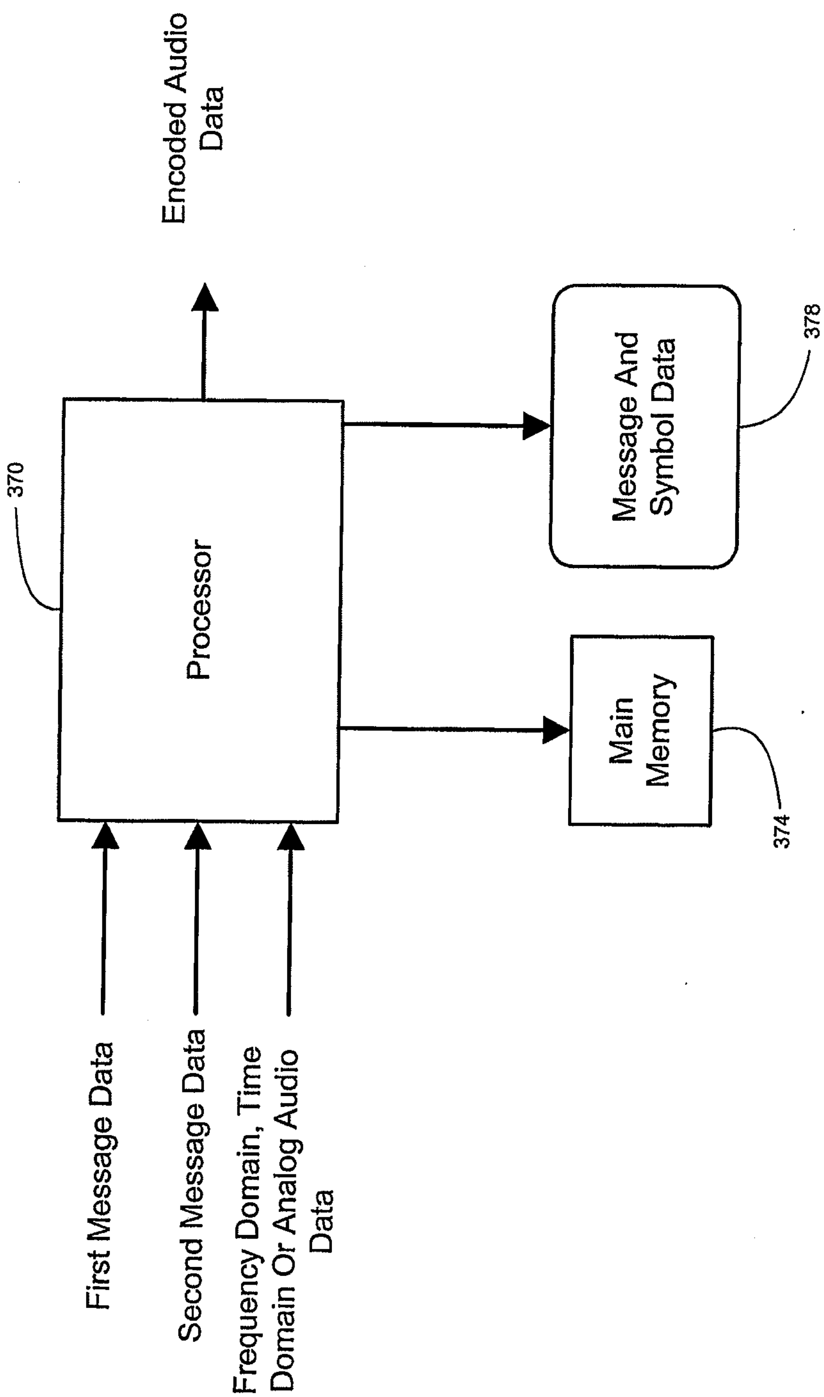

Encoded Audio Data
370
Processor
Message And Symbol Data
378
Main Memory
374
First Message Data
Second Message Data
Frequency Domain, Time Domain Or Analog Audio Data

FIGURE 10